The present application is a continuation of PCT International Application No. PCT/JP02/09022 filed on September 5 , 2002, which is hereby incorporated by reference.

SPECIFICATION

DRESSING TOOL, DRESSING DEVICE, DRESSING METHOD, PROCESSING DEVICE AND SEMICONDUCTOR DEVICE PRODUCING METHOD

Technical Field

The present invention relates to a dressing tool, a dressing apparatus and a dressing method which are used to dress the working surface of a working tool that is used to perform polishing, grinding or lapping, etc., a working apparatus which has such a dressing tool or dressing apparatus, and a semiconductor device manufacturing method.

Background Art

Working tools that perform polishing, grinding or lapping, etc., deteriorate due to the fact that clogging of the working surface progresses as the working time increases. Accordingly, such working tools are maintained by performing periodic dressing so that favorable working can always be performed. For example, such working tools include polishing pads that are used in chemical-mechanical polishing apparatuses (CMP apparatuses) that perform polishing on circuit constituent films, etc., that are formed on the surfaces of wafers in semiconductor wafer manufacturing processes. Such polishing pads are also dressed at specified intervals by means of a dressing tool. Fore example, such dressing methods and apparatuses include those disclosed in Japanese Patent Application Kokai No. H10-71557.

A conventional example of the dressing of the polishing surface of such a polishing pad using a dressing tool is shown in Figure 18. Here, an example is shown in which a doughnut disk-form pad surface (working surface) 101 in a polishing pad 100 constituting a working tool is dressed by means of a dressing tool 110 which has a ring-form dressing surface 111. The dressing surface 111 of the dressing tool 110 consists of a narrow ring-form flat surface with a width indicated by hatching in the figure; this dressing surface 111 faces the pad surface 101. Furthermore, dressing (recovery of the surface state and flattening) of the pad surface 101 is accomplished by causing the dressing surface 111 to contact the pad surface 101 as shown in Figure 18 while causing the dressing tool 110 to rotate

about a rotational axis O2 that passes through the center point of the dressing tool 110 and extends perpendicular to the dressing surface 111, in a state in which the polishing pad 100 is caused to rotate about a rotational axis O1 that passes through the center point of the polishing pad 100 and extends perpendicular to the pad surface 101.

In cases where dressing is performed in this way, the amount of the pad surface 101 that is ground away by the dressing tool 110 is greater at the inner circumferential position A and outer circumferential position C of the pad surface 101 than at the middle circumferential position B. As a result, the following problem arises: namely, as is shown in Figure 18 (A), the cross-sectional shape of the pad surface 101 following dressing is such that the inner circumferential position A and outer circumferential position C of the pad surface 101 are lower than the middle circumferential position B, so that the cross-sectional shape in the radial direction tends to assume a convex shape at the top. The reason for this is as follows: namely, the amount of the pad surface 101 that is ground away by the dressing tool 110 corresponds to the contact length of the dressing surface 111 on the circumference of the pad surface 101, and as is clearly seen from the figures, the contact lengths S1 and S3 at the inner circumferential position A and outer circumferential position C are longer than the contact length S2 at the middle circumferential position B.

Furthermore, the following problem also arises: namely, in order to cause uniform contact of the dressing surface 111 of the rotating dressing tool 110 with the pad surface 101 of the polishing pad 100 that is thus rotating, either the polishing pad 100 or the dressing tool 110 must be centered by means of a gimbal centering mechanism, etc., so that the construction of the dressing apparatus tends to become complicated.

Furthermore, even if support by means of a centering mechanism is thus provided, if the dressing tool 110 deviates toward the outer circumferential side or inner circumferential side of the pad surface 101, there is a resulting imbalance in the contact surface pressure between the dressing surface 111 and pad surface 101, so that there is a problem in terms of a loss of flatness of the pad surface 101 following dressing. For example, in cases where the rotational axis O2 of the dressing tool 110 deviates toward the outer circumferential side from the state shown in Figure 18 (i.e., in cases where the rotational axis O2 deviates so that this rotational axis is separated from the rotational axis O1 of the polishing pad 100 in Figure 18), the following problem arises: namely, the contact surface pressure on the outer circumferential side is increased, so that the outer circumferential position C becomes lower than the inner circumferential position A as shown in Figure 18 (B), thus resulting in a cross-sectional shape in which the overall pad surface 101 following dressing assumes a convex shape at the top. Conversely, in cases where the rotational axis O2 of the dressing tool 110 deviates toward the

inner circumferential side from the state shown in Figure 18 (i.e., in cases where the rotational axis O2 deviates so that this rotational axis is closer to the rotational axis O1 of the polishing pad 100 in Figure 18), the following problem is encountered: specifically, the contact surface pressure on the inner circumferential side is increased, so that the inner circumferential position A becomes lower than the outer circumferential position C as shown in Figure 18 (C), thus resulting in a cross-sectional shape in which the overall pad surface 101 following dressing assumes a concave shape at the top.

In the case of conventional dressing tools, abrasive grains such as diamond particles are distributed at a constant mean distribution density over the entire dressing surface. Accordingly, the grinding capacity per unit area in various parts of the dressing surface is constant over the entire surface. Furthermore, the shape of a conventional dressing surface is circular or annular.

Since the dressing tool is used to dress the polishing pad as described above, it is not desirable that the mean distribution density of the abrasive grains be as high as possible; instead, there is an optimal mean distribution density for creating an appropriate roughness in the polishing surface of the polishing pad. Accordingly, the abrasive grains should be distributed at such a mean distribution density over the entire dressing surface. Specifically, conventional technical common sense

dictates that the abrasive grains should be distributed at a certain constant mean distribution density over the entire dressing surface.

However, in the case of the above-mentioned conventional dressing tools, it is difficult to flatten the polishing surface of the polishing pad with a high degree of precision. As a result of such a low flatness of the polishing pad, it is difficult to polish semiconductor wafers, etc., to a flat surface with a high degree of precision using such a polishing pad.

Furthermore, dressing is performed by causing contact between the polishing surface of the polishing pad supported on a substrate and the dressing surface of the dressing tool, and causing relative motion between the above-mentioned substrate and dressing tool. For example, the above-mentioned relative motion is accomplished by causing both the dressing tool and the substrate that supports the polishing pad to rotate. Because of manufacturing error, etc., it is difficult to position the rotational axis of the above-mentioned substrate and the rotation axis of the dressing tool so that these axes are perfectly parallel; accordingly, the two rotational axes are actually slightly inclined relative to each other.

Conventionally, in order to dress the polishing pad to a flat surface in spite of such an inclination, a gimbal mechanism has been used between the dressing tool and the rotational axis of this dressing tool, and dressing has been performed using

the angular tracking characteristics of the dressing tool obtained by means of this gimbal mechanism. For example, in the case of a CMP apparatus, it is necessary that the semiconductor wafers, etc., be polished to a flat surface with a high degree of precision; consequently, the polishing pad must also be flat with a high degree of precision. Conventionally, therefore, in cases where the polishing pad used in a CMP apparatus, etc., is dressed, the utilization of the angular tracking characteristics obtained by means of the above-mentioned gimbal mechanism has been considered indispensable.

In recent years, however, because of the increasing fineness of semiconductor devices, the polishing of semiconductor wafers, etc., to a flat surface with an even higher degree of precision has become necessary. Consequently, it has become necessary that polishing pads also be flat with an even higher degree of precision. Accordingly, there is now a need to dress polishing pads to a flat surface with an even higher degree of precision.

Disclosure of the Invention

The present invention was devised in light of these problems. First of all, it is an object of the present invention to provide a dressing tool and apparatus which can sufficiently maintain the flatness of the working surface following dressing, and a manufacturing apparatus using a working tool which is dressed by means of such

a dressing apparatus. Furthermore, it is also an object of the present invention to provide a dressing tool and apparatus that have a construction which is such that there is no need for a centering mechanism in the apparatus that holds the working tool and dressing tool during dressing.

Secondly, it is an object of the present invention to provide a dressing tool which can ensure the flatness of the polishing surface of the polishing pad following dressing with a high degree of precision, and a dressing apparatus using this dressing tool.

Third, it is an object of the present invention to provide a dressing method and apparatus which can dress a polishing pad to a flat surface with a higher degree of precision, to provide a polishing apparatus which can polish an object of polishing using this polishing pad that has been dressed to a flat surface with a high degree of precision, and to provide a semiconductor device manufacturing method which makes it possible to manufacture semiconductor devices at a higher yield and lower cost than conventional semiconductor device manufacturing methods.

Inventions that are used to achieve these objects will be described below. However, the respective inventions are not inventions that achieve all of the above-mentioned objects of the invention. Which objects are achieved by which inventions

will be clear from the constructions of the inventions, and from the working configurations and embodiments of the inventions that are described below.

The first invention that is used to achieve the above-mentioned objects is a dressing tool which performs the dressing of a working tool that has a doughnut disk-form or circular disk-form working surface, this dressing tool being characterized by the fact that the tool has a substantially rectangular dressing surface that performs dressing by contacting the working surface of the above-mentioned working tool, and the above-mentioned dressing surface is disposed so that the centerline of the above-mentioned dressing surface in the direction of the short sides of the above-mentioned substantially rectangular shape coincides with the radial direction passing through the center of the above-mentioned doughnut disk or circular disk of the above-mentioned working tool during dressing.

The second invention that is used to achieve the above-mentioned objects is the above-mentioned first invention which is further characterized by the fact that the shapes of both long sides of the above-mentioned substantially rectangular shape that extend parallel to the above-mentioned centerline in the direction of the short sides are shapes which are such that when the above-mentioned dressing surface is caused to contact the above-mentioned working surface, the contact length between the above-mentioned working surface and the above-mentioned

dressing surface is equal at all positions in the radial direction of the above-mentioned working surface.

The third invention that is used to achieve the above-mentioned objects is a dressing apparatus which is characterized by the fact that this apparatus has the dressing tool of the above-mentioned first invention or second invention, and a working tool holding mechanism which holds a working tool that has a doughnut disk-form or circular disk-form working surface, and which causes this working tool to rotate about an axis that passes through the center of the above-mentioned doughnut disk or circular disk perpendicular to the above-mentioned working surface.

The fourth invention that is used to achieve the above-mentioned objects is the above-mentioned third invention, which is further characterized by the fact that this apparatus has a plurality of dressing tools, and these dressing tools are disposed so that the plurality of dressing tools simultaneously dress the above-mentioned working surface.

The fifth invention that is used to achieve the above-mentioned objects is a working apparatus which has the above-mentioned working tool that is dressed by the dressing tool constituting the above-mentioned first invention or second invention.

The sixth invention that is used to achieve the above-mentioned objects is a working apparatus which has the above-mentioned working tool that is dressed by the dressing apparatus constituting the above-mentioned third invention or fourth invention.

The seventh invention that is used to achieve the above-mentioned objects is a dressing tool which is used to dress the working surface of a working tool that has a circular outer circumference, this dressing tool being characterized by the fact that the dressing tool comprises a dressing surface which is constructed from a circular region that has a first cutting capacity per unit area, and an annular region that is concentric with the above-mentioned circular region and that has a second cutting capacity per unit area that is higher than the above-mentioned first cutting capacity per unit area, the diameter of the above-mentioned circular region of the above-mentioned dressing surface is greater than the effective use width within the radius of the above-mentioned working surface, and the external diameter of the above-mentioned annular region of the above-mentioned dressing surface is substantially half of the external diameter of the above-mentioned working surface.

The eighth invention that is used to achieve the above-mentioned objects is a dressing tool which is used to dress the working surface of a working tool that has a circular outer circumference, this dressing tool being characterized by the fact that

the dressing tool comprises a dressing surface which is constructed from a circular region in which abrasive grains are distributed at a first mean distribution density, and an annular region which is concentric with the above-mentioned circular region, and in which abrasive grains are distributed at a second mean distribution density that is higher than the above-mentioned first mean distribution density, the diameter of the above-mentioned circular region of the above-mentioned dressing surface is greater than the effective use width within the radius of the above-mentioned working surface, and the external diameter of the above-mentioned annular region of the above-mentioned dressing surface is substantially half of the external diameter of the above-mentioned working surface.

The ninth invention that is used to achieve the above-mentioned objects is the above-mentioned eighth invention, which is further characterized by the fact that the above-mentioned first mean distribution density is 10% to 50% of the above-mentioned second mean distribution density.

The tenth invention that is used to achieve the above-mentioned objects is a dressing apparatus which is characterized by the fact that this dressing apparatus comprises the dressing tool constituting any of the above-mentioned seventh through ninth inventions, and a rotational mechanism which causes this dressing tool to rotate.

In this invention, since the dressing tool constituting any of the above-mentioned seventh through ninth inventions is provided, dressing can be performed utilizing the actions and effects of the respective tools.

The eleventh invention that is used to achieve the above-mentioned objects is a dressing method for dressing the working surface of a working tool supported on a substrate by causing contact between this working surface and the dressing surface of a dressing tool and causing relative motion between the above-mentioned substrate and the above-mentioned dressing tool, this dressing method being characterized by the fact that this method comprises a setting stage in which the relative inclination of the above-mentioned dressing surface with reference to the above-mentioned substrate is adjusted to a desired inclination and set, and a dressing stage in which the above-mentioned working surface is dressed while maintaining the above-mentioned relative inclination set in the above-mentioned setting stage.

The twelfth invention that is used to achieve the above-mentioned objects is the above-mentioned eleventh invention, which is further characterized by the fact that the above-mentioned setting stage includes a stage in which information corresponding to the surface shape of the above-mentioned working surface is obtained, and a stage in which the above-mentioned relative inclination is adjusted and set on the basis of the above-mentioned information.

The thirteenth invention that is used to achieve the above-mentioned objects is the above-mentioned eleventh or twelfth invention, which is further characterized by the fact that the above-mentioned setting stage and the above-mentioned dressing stage are alternately repeated a multiple number of times each.

The fourteenth invention that is used to achieve the above-mentioned objects is any of the above-mentioned eleventh through thirteenth inventions, which is further characterized by the fact that the dressing of the above-mentioned working surface in the above-mentioned dressing stage is performed in a state in which a portion of the above-mentioned dressing surface protrudes from the circumference of the above-mentioned working surface.

The fifteenth invention that is used to achieve the above-mentioned objects is any of the above-mentioned eleventh through fourteenth inventions, which is further characterized by the fact that the above-mentioned relative inclination is an inclination about a specified axial line that is substantially perpendicular to a straight line passing through the vicinity of the center of the above-mentioned working surface and the vicinity of the center of the above-mentioned dressing surface.

The sixteenth invention that is used to achieve the above-mentioned objects is a dressing apparatus which dresses the working surface of a working tool supported on a substrate by causing contact between this working surface and the dressing surface of a dressing tool and causing relative motion between the above-mentioned substrate and the above-mentioned dressing tool, this dressing apparatus being characterized by the fact that the apparatus comprises an inclination adjustment mechanism that can adjust the relative inclination of the above-mentioned dressing surface with reference to the above-mentioned substrate to a desired inclination and set this inclination, and a moving mechanism which dresses the above-mentioned working surface by causing relative motion between the above-mentioned substrate and the above-mentioned dressing tool while maintaining the above-mentioned relative inclination set by the above-mentioned inclination adjustment mechanism.

The seventeenth invention that is used to achieve the above-mentioned objects is the above-mentioned sixteenth invention, which is further characterized by the fact that the dressing apparatus is an apparatus that dresses the working surface of a working tool that has a circular outer circumference, the above-mentioned dressing tool comprises a dressing surface which is constructed from a circular region that has a first cutting capacity per unit area, and an annular region that is concentric with the above-mentioned circular region and that has a second cutting capacity per unit area that is higher than the above-mentioned first cutting

capacity per unit area, the diameter of the above-mentioned circular region of the above-mentioned dressing surface is greater than the effective use width within the radius of the above-mentioned working surface, and the external diameter of the above-mentioned annular region of the above-mentioned dressing surface is substantially half of the external diameter of the above-mentioned working surface.

The eighteenth invention that is used to achieve the above-mentioned objects is the above-mentioned sixteenth invention or seventeenth invention, which is further characterized by the fact that the dressing apparatus comprises a control part that operates the above-mentioned inclination adjustment mechanism on the basis of information corresponding to the surface shape of the above-mentioned working surface so that the above-mentioned relative inclination is a desired inclination.

The nineteenth invention that is used to achieve the above-mentioned objects is the above-mentioned eighteenth invention, which is further characterized by the fact that the dressing apparatus comprises a measuring part that acquires the above-mentioned information.

The twentieth invention that is used to achieve the above-mentioned objects is a dressing apparatus which dresses the working surface of a working tool supported on a substrate by causing contact between this working surface and the

dressing surface of a dressing tool and causing relative motion between the above-mentioned substrate and the above-mentioned dressing tool, this dressing apparatus being characterized by the fact that the apparatus comprises an inclination adjustment mechanism that can adjust the relative inclination of the above-mentioned dressing surface with reference to the above-mentioned substrate to a desired inclination and set this inclination, a moving mechanism which dresses the above-mentioned working surface by causing relative motion between the above-mentioned substrate and the above-mentioned dressing tool while maintaining the above-mentioned relative inclination set by the above-mentioned inclination adjustment mechanism, a measuring part which acquires information corresponding to the surface shape of the above-mentioned working surface, and a control part which, in response to specified command signals, (i) causes the above-mentioned dressing to be performed by operating the above-mentioned moving mechanism, (ii) makes a judgement as to whether or not the above-mentioned relative inclination that is currently set is the desired inclination on the basis of the above-mentioned information acquired by the above-mentioned measuring part following the dressing performed in the above-mentioned (i), (iii) ends the adjustment of the above-mentioned relative inclination in cases where it is judged in the above-mentioned (ii) that the currently set inclination is the desired inclination, and (iv) repeats the operation from the above-mentioned (i) on after operating the above-mentioned inclination adjustment mechanism so that the above-mentioned relative inclination is adjusted to the desired inclination or an

inclination that approaches this desired inclination in cases where it is judged in the above-mentioned (ii) that the currently set inclination is not the desired inclination.

The twenty-first invention that is used to achieve the above-mentioned objects is the above-mentioned twentieth invention, which is further characterized by the fact that the dressing apparatus is an apparatus that dresses the working surface of a working tool that has a circular outer circumference, the above-mentioned dressing tool comprises a dressing surface which is constructed from a circular region that has a first cutting capacity per unit area, and an annular region that is concentric with the above-mentioned circular region and that has a second cutting capacity per unit area that is higher than the above-mentioned first cutting capacity per unit area, the diameter of the above-mentioned circular region of the above-mentioned dressing surface is greater than the effective use width within the radius of the above-mentioned working surface, and the external diameter of the above-mentioned annular region of the above-mentioned dressing surface is substantially half of the external diameter of the above-mentioned working surface.

The twenty-second invention that is used to achieve the above-mentioned objects is any of the above-mentioned sixteenth through twenty-first inventions, which is further characterized by the fact that the dressing of the above-mentioned working surface is performed in a state in which a portion of the above-mentioned

dressing surface protrudes from the circumference of the above-mentioned working surface.

The twenty-third invention that is used to achieve the above-mentioned objects is any of the above-mentioned sixteenth through twenty-second inventions, which is further characterized by the fact that the above-mentioned relative inclination is an inclination about a specified axial line that is substantially perpendicular to a straight line passing through the vicinity of the center of the above-mentioned working surface and the vicinity of the center of the above-mentioned dressing surface.

The twenty-fourth invention that is used to achieve the above-mentioned objects is a working apparatus which comprises a working tool that has a working surface, and a holding part that holds the workpiece, and which works the above-mentioned workpiece by applying a load between the above-mentioned working surface of the above-mentioned working tool and the above-mentioned workpiece and causing the relative motion of the above-mentioned working tool and the above-mentioned workpiece, this working apparatus being characterized by the fact that the above-mentioned working surface is dressed by the dressing method of any of the above-mentioned eleventh through fifteenth inventions.

The twenty-fifth invention that is used to achieve the above-mentioned objects is a working apparatus which comprises a working tool that has a working surface, and a holding part that holds the workpiece, and which works the above-mentioned workpiece by applying a load between the above-mentioned working surface of the above-mentioned working tool and the above-mentioned workpiece and causing the relative motion of the above-mentioned working tool and the above-mentioned workpiece, this working apparatus being characterized by the fact that the above-mentioned working surface is dressed by the dressing apparatus of any of the above-mentioned sixteenth through twenty-third inventions.

The twenty-sixth invention that is used to achieve the above-mentioned objects is a working apparatus which comprises a working tool that has a working surface, and a holding part that holds the workpiece, and which works the above-mentioned workpiece by applying a load between the above-mentioned working surface of the above-mentioned working tool and the above-mentioned workpiece and causing the relative motion of the above-mentioned working tool and the above-mentioned workpiece, this working apparatus being characterized by the fact that the apparatus comprises the dressing apparatus of any of the above-mentioned sixteenth through twenty-third inventions.

The twenty-seventh invention that is used to achieve the above-mentioned objects is a semiconductor device manufacturing method which is characterized by

the fact that this method has a process in which the surface of a semiconductor wafer is flattened using the working apparatus of the above-mentioned fifth or sixth inventions, or of any of the above-mentioned twenty-fourth through twenty-sixth inventions.

Brief Description of the Drawings

Figure 1 is a schematic structural diagram which shows the construction of a dressing apparatus constituting a working configuration of the present invention in model form.

Figure 2 is a schematic plan view which shows the positional relationship between the polishing pad and the dressing apparatus in the dressing apparatus shown in Figure 1.

Figure 3 is a graph which shows the results of a simulation of the flatness of the polishing pad surface in a case where dressing was performed using a dressing tool with a rectangular shape.

Figure 4 is an explanatory diagram which shows the contact length relationship between the rectangular dressing tool of the present invention and the polishing pad.

Figure 5 is a diagram which shows an example of the shapes of the left-right sides in a case where a correction is performed so that the contact lengths with the polishing pad in the circumferential direction are all equal in the rectangular dressing tool of the present invention.

Figure 6 is a schematic plan view which shows a dressing apparatus constituting a working configuration of the present invention.

Figure 7 is a schematic structural diagram which shows the construction of a dressing apparatus constituting a working configuration of the present invention.

Figure 8 is a schematic plan view which shows in model form the positional relationship between the dressing surface of the dressing tool and the polishing pad during the dressing of the polishing pad by the dressing apparatus shown in Figure 7.

Figure 9 is an enlarged schematic sectional view which shows in model form the dressing tool used in the dressing apparatus shown in Figure 7.

Figure 10 is a diagram which shows the results of a simulation of the thickness distribution of the polishing pad following dressing.

Figure 11 is a diagram which shows the results of another simulation of the thickness distribution of the polishing pad following dressing.

Figure 12 is a schematic structural diagram which shows in model form the construction of a polishing apparatus constituting a working configuration of the present invention.

Figure 13 is a schematic plan view which shows in model form the positional relationship between the dressing surface of the dressing tool and the polishing pad during the dressing of the polishing pad in the polishing apparatus shown in Figure 12.

Figure 14 is a schematic flow chart which shows the operation of the inclination adjustment control.

Figure 15 is a schematic structural diagram which shows in model form the construction of a dressing apparatus constituting a working configuration of the present invention.

Figure 16 is a schematic plan view which shows in model form the positional relationship between the dressing surface of the dressing tool and the polishing pad in the dressing apparatus shown in Figure 15.

Figure 17 is a flow chart which shows a semiconductor device manufacturing process.

Figure 18 shows a schematic diagram and sectional view which illustrate the construction of a conventional dressing apparatus and the shape of the working surface following dressing.

Best Mode for Carrying Out the Invention

Preferred working configurations of the present invention will be described below with reference to the figures. However, the descriptions of these working configurations do not limit the scope of the present invention.

[First Working Configuration]

A dressing apparatus DA for a polishing pad constructed using the dressing tool 2 of the present invention is shown in Figure 1. This dressing apparatus DA is an apparatus which dresses a pad surface (polishing surface) 15a of a polishing pad

15 used in a CMP apparatus, and is constructed from a pad holding mechanism 10 which holds the polishing pad 15 by vacuum chucking, etc., and causes this polishing pad 15 to rotate, and a dressing tool holding mechanism 1 which has a dressing tool 2 that dresses the pad surface 15a of the polishing pad 15 that is held and caused to rotate by the above-mentioned pad holding mechanism 10. The pad holding mechanism 10 is constructed from a pad holding head 11 which holds the polishing pad 15 by vacuum chucking, a rotating shaft 12 which is connected to the pad holding head 11, and a rotational driving device (not shown in the figures) which causes the pad holding head 11 to rotate about its rotational axis O3 via this rotating shaft 12. Furthermore, as is shown in Figure 2, the polishing pad 15 consists of a plate-form member which has a doughnut disk-form pad surface 15a, and is held by the pad holding head 11 so that an axial line that passes through the center point of the polishing pad 15 and is perpendicular to the pad surface 15a constitutes the above-mentioned rotational axis O3.

The dressing tool holding mechanism 1 is constructed from the dressing tool 2 which has a rectangular dressing surface 3 as shown in Figure 2, and a holding cylinder mechanism 5 which holds this dressing tool 2 so that the dressing tool 2 is free to move upward and downward. The dressing tool 2 has a length dimension that is slightly greater than the radial dimension of the pad surface 15a of the polishing pad 15, and has a rectangular dressing surface 3 in which the width dimension of the left-right sides (long sides) 3a and 3b is w. The holding cylinder

mechanism 5 comprises a cylinder tube 6 which is fastened to the surface of a base 4, a piston head 7a which is inserted into the cylinder tube 6 so that this piston head 7a is free to slide in the axial direction, and a rod 7b which is connected to this piston head 7a, and which passes through the cylinder tube 6 and extends upward. The dressing tool 2 is held by being fastened to the upper end of the rod 7b.

The dressing tool holding mechanism 1 holds the dressing tool 2 so that the dressing surface 3 is caused to face the pad surface 15a of the polishing pad 15 that is held and rotated by the pad holding mechanism 10. In this case, as is shown in Figure 2, the dressing tool 2 is held so that the centerline L1 of the dressing surface 3 in the direction of width (short-side direction) extends in the radial direction of the doughnut disk-form pad surface 15a, and the dressing tool 2 is raised by the holding cylinder mechanism 5 so that the dressing surface 3 is pressed against the pad surface 15a. The pressing force in this case is set at an appropriate value by means of the holding cylinder mechanism 5, so that the dressing of the pad surface 15a is performed.

In the case of the dressing apparatus DA constructed as described above, since the dressing tool 2 is fastened and held, and the polishing pad 15 is caused to rotate by the pad holding mechanism 10, there is no need for a centering mechanism such as that used in a conventional dressing apparatus, so that the construction of the apparatus is simplified.

However, in the case of dressing by means of a dressing tool 2 which has a rectangular dressing surface 3 as described above, the contact length S of the dressing surface 3 in the circumferential direction of the pad surface 15a varies (although only slightly) according to the position in the radial direction. Accordingly, there is a possibility that the flatness of the pad surface 15a following dressing will drop. For example, as is shown in Figure 2, if the contact length Si in the circumferential direction at the inner circumferential position A and the contact length So in the circumferential direction at the outer circumferential position B are compared, Si > So since the curvature of the inner circumferential position A is greater than the curvature of the outer circumferential position B. Consequently, a greater amount of dressing is performed on the inner circumferential side, so that the pad surface 15a tends to assume an overall cross-sectional shape that is concave at the top as shown in Figure 18 (C).

Figure 3 shows simulation results regarding this. Here, the position in the radial direction of the pad surface 15a of the polishing pad 15 (as is seen from this figure, the pad surface 15a has a doughnut disk shape with an internal diameter of approximately 60 mm and an external diameter of approximately 170 mm) is shown on the horizontal axis, and the amount of variation (%) of the pad surface following dressing with respect to a flat surface is shown on the vertical axis. In this simulation, the amounts of variation of the pad surface 15a with respect to a flat

surface are shown for cases where dressing was performed under the same conditions using five types of dressing tools 2 in which the width dimensions w of the dressing surfaces 3 were 10 mm, 20 mm, 30 mm, 40 mm and 50 mm, respectively. As is seen from this figure, the flatness is improved as the width dimension w is smaller; for example, a dressing tool 2 which has a dressing surface 3 in which w = approximately 10 to 20 mm is adequate for practical use.

However, it is desirable to increase the dressing efficiency by shortening the dressing time; in order to accomplish this, an increase in the width dimension w of the dressing surface 3 is desired. Here, we will consider the cause of the drop in flatness that accompanies an increase in the width dimension w as shown in Figure 3. As is shown in Figure 4, in regard to the contact length S in the circumferential direction at a circumferential position D of radius r in a case where the dressing surface 3 (width dimension w) of the dressing tool 2 is caused to contact the polishing surface 15a of the polishing pad 15, these relationships can be expressed by the following Equations (1) and (2), where 2β is the circumferential angle corresponding to this contact length S.

$$\beta = \arcsin(w/(2r)) \qquad \ldots (1)$$

$$s = r \times 2\beta \qquad \ldots (2)$$

Here, if the shapes of the left-right sides 3a and 3b of the dressing surface 3 are corrected so that the contact length s determined by Equation (2) is equal for all radii r (i.e., at all circumferential positions), then the amount of dressing will be the same over the entire pad surface 15a, so that the pad surface 15a can be made flat following dressing even if the width w is increased. Furthermore, an example of the shapes of the left-right sides 3a' and 3b' of the dressing surface 3' corrected in this manner is shown in Figure 5. In Figure 5, the horizontal axis shows the position in the radial direction (direction of the X axis) from the center position of the pad, and the vertical axis shows the position in the direction of the Y axis perpendicular to this. The area 3' surrounded by the substantially rectangular line is the dressing surface. In the case of a dressing tool 2 comprising a dressing surface 3' which has left-right sides 3a' and 3b' that are corrected in this manner, the dressing efficiency can be increased by increasing the width dimension w.

Furthermore, if a dressing apparatus is constructed as shown in Figure 6 using a plurality of dressing tools 2 which have a dressing surface 3' with such a large width dimension w, the dressing of the pad surface 15a can be accomplished efficiently in a shorter time. Moreover, in cases where a plurality of dressing tools are thus used, the respective dressing tools need not be tools in which the shapes of the left-right sides are corrected as described above; these tools may be rectangular tools with a small width dimension w.

The manufacturing apparatus of the invention in this first working configuration is constructed with a polishing pad 15 which is dressed by a dressing apparatus DA constructed using the dressing tool 2 described above; a CMP apparatus which polishes wafers using this polishing pad 15 corresponds to the working apparatus of the above-mentioned sixth invention. Furthermore, it is desirable that the respective dressing tools be attached to the same substrate.

Furthermore, in the first working configuration, the polishing pad had a doughnut disk-form shape; however, the above-mentioned first through sixth inventions can also be applied to a polishing pad with a circular disk shape.

In the invention of the first working configuration described above, since dressing is performed by causing only the working tool to rotate in a state in which the dressing tool is held in a fixed position, there is no need for a centering mechanism, so that the construction of the apparatus can be simplified. Furthermore, since a dressing tool which has a substantially rectangular shape is used, the contact length on the circumference between the working surface and the dressing surface is the same at all positions in the radial direction, so that the flatness of the working surface following dressing can be improved.

[Second Working Configuration]

Figure 7 is a schematic structural diagram which shows a dressing apparatus constituting a second working configuration of the present invention. Figure 8 is a schematic plan view which shows in model form the positional relationship between the dressing surface of the dressing tool 21 and the polishing pad 25 during the dressing of the polishing pad 25. Figure 9 is an enlarged schematic sectional view which shows the dressing tool 21 in model form.

As is shown in Figure 7, the dressing apparatus of the present working configuration comprises a dressing tool 21 and a rotational mechanism 23 which causes the dressing tool 21 to rotate with respect to a base 22. This dressing apparatus is constructed so that this apparatus dresses the polishing surface 25a of a CMP apparatus polishing pad 25 supported on a substrate 24. The substrate 24 and polishing pad 25 may constitute the CMP apparatus polishing tool itself, or the substrate 24 may be a member that is separate from the polishing tool. In the former case, the dressing apparatus according to the present working configuration is disposed in the dressing station (dressing zone) of the CMP apparatus.

As is shown in Figure 8, the polishing surface 25a of the polishing pad 25 has a circular outer circumference. In the present example, the polishing pad 25 is constructed with an annular shape in which the central part is removed. Of course, the polishing pad that is the object of dressing by the dressing apparatus of the present working configuration is not limited to an annular polishing pad; for

example, this polishing pad may also be a circular polishing pad in which the central part is not removed. In the present working configuration, the entire annular polishing surface 25a of the polishing pad 25 forms an effective use region that can be effectively used in the polishing of an object of polishing such as a semiconductor wafer. The effective use width within the radius of the polishing pad 25 is half the difference between the external diameter and internal diameter.

The polishing pad 25 and substrate 24 are arranged so that these parts can be rotated and moved upward and downward as indicated by the arrows a and b in Figure 7 by a mechanism (not shown in the figures) using electric motors as actuators. Furthermore, the substrate 24 is mechanically connected to a rotating shaft 26 via a gimbal mechanism (not shown in the figures). Of course, it is not absolutely necessary to install a gimbal mechanism. Furthermore, in Figure 8, O1 indicates the center of the polishing pad 25, and the polishing pad 25 rotates about this center O1 as the center of rotation.

In the present working configuration, as is shown in Figure 9, the dressing tool 21 has a substrate 31 consisting of a disk, diamond particles 32 used as abrasive grains which are distributed on the upper surface of the substrate 31, and a nickel plating 33 that fastens the diamond particles 32 to the substrate 31. In the circular region R1 in the central part of the upper surface of the dressing tool 21, the diamond particles 32 are distributed at a mean distribution density D1. On the

other hand, in the annular region R2 that is concentric with the circular region R1 on the upper surface of the dressing tool 21, the diamond particles 32 are distributed at a mean distribution density D2 that is higher than the mean distribution density D1.

In cases where the mean distribution density D1 exceeds 50% of the mean distribution density D2 when the polishing pad used in the CMP polishing apparatus dressed, the thickness distribution in the radial direction of the polishing pad 25 becomes a thickness distribution that is concave in the downward direction, so that the flatness required in the polishing pad of the CMP apparatus cannot be achieved. On the other hand, in cases where the mean distribution density D1 is less than 10% of the mean distribution density D2, the thickness distribution in the radial direction of the polishing pad 25 becomes a thickness distribution that is convex in the upward direction, so that the flatness required in the polishing pad of the CMP apparatus cannot be achieved. Accordingly, it is desirable that the mean distribution density D1 be 10% to 50% of the mean distribution density D2.

In the present working configuration, a concentric circular groove 31a is formed in the substrate 31 between the circular region R1 and annular region R2. However, it is not absolutely necessary that such as groove 31a be formed. The dressing surface of the dressing tool 21 is constructed by the circular region R1 and annular region R2. In Figure 8, O2 indicates the center of the circular region R1

and annular region R2, and the rotational mechanism 23 causes the dressing tool 21 to rotate about this center O2 as the center of rotation.

Since the mean distribution density D2 is set higher than the mean distribution density D1 as was described above, the cutting capacity per unit area of the annular region R2 is higher than the cutting capacity per unit area of the circular region R1. Furthermore, the present working configuration is an example in which the dressing surface is formed using diamond particles 32 as abrasive grains. However, the present invention is not limited to this; for example, it would also be possible to set the cutting capacity per unit area of the annular region R2 at a value that is higher than the cutting capacity per unit area of the circular region R1 by using other cutting edges instead of using abrasive particles, and appropriately setting the distribution density of these cutting edges.

Furthermore, the above-mentioned dressing tool 21 can basically be manufactured by a method using electrodeposition (similar to that used in conventional dressing tools) in which diamond particles are used as abrasive grains. Here, in order to vary the mean distribution density of the diamond particles 32 in the respective regions R1 and R2, the diamond particles 32 can be separately distributed in the two regions R1 and R2, for example, by masking the annular region R2 with a mask plate, etc., when the diamond particles 32 are distributed in the circular region R1, and masking the circular region R1 with a mask plate, etc.,

when the diamond particles 32 are distributed in the annular region R2. Of course, it goes without saying that various methods can be used as the manufacturing method of the dressing tool 21.

As is shown in Figure 8, the diameter of the circular region R1 of the dressing surface is set so that this diameter is slightly larger than the above-mentioned effective use width within the radius of the polishing pad 25. The external diameter of the annular region R2 of the dressing surface is set at approximately half of the external diameter of the polishing pad 25.

In this dressing apparatus, as is shown in Figures 7 and 8, the polishing surface 25a of the polishing pad 25 is dressed by respectively rotating the polishing pad 25 and dressing tool 21 as indicated by the arrows a and c in a state in which the polishing surface (the undersurface in the present working configuration) of the polishing pad 25 is pressed against the dressing surface of the dressing tool 21 with a specified pressure (load)

In the present working configuration, since the dressing surface of the dressing tool 21 is constructed from a circular region R1 which has a relatively low cutting capacity per unit area and an annular region R2 which has a relatively high cutting capacity per unit area, the polishing surface of the polishing pad can be

flattened with a high degree of precision by appropriately setting these cutting capacities.

In order to confirm this effect, the present inventors obtained the thickness distribution in the radial direction of a polishing pad 25 (that was initially completely flat) following dressing for a specified period of time by means of a dressing apparatus similar to the dressing apparatus of the above-mentioned working configuration or a dressing apparatus constituting a modification of this dressing apparatus, by means of a simulation using the equation of Preston. The simulation results are shown in Figures 10 and 11.

The simulation conditions when the simulation results A shown in Figure 10 were obtained were as follows: specifically, in the above-mentioned working configuration, the internal diameter of the annular polishing pad 25 was set at 60 mm, the external diameter of the polishing pad 25 was set at 170 mm, the load between the polishing pad 25 and the dressing tool 21 was set at 3 kgf, the rotational speed of the polishing pad 25 was set at 395 rpm, the rotational speed of the dressing tool 21 was set at 175 rpm, the rotational directions of the polishing pad 25 and dressing tool 21 were set as the same direction, the diameter of the circular region R1 of the dressing tool 21 was set at 70 mm, the internal diameter of the annular region R2 of the dressing tool 21 was set at 80 mm, the external diameter of the annular region R2 was set at 100 mm, the distance between the

center O1 of the polishing pad 25 and the center O2 of the dressing tool 21 was set at 52.5 mm, and the mean distribution density D1 of the abrasive grains in the circular region R1 when the mean distribution density D2 of the abrasive grains in the annular region R2 was normalized to 1 was set at 0.25 (i.e., D1/D2 = 0.25).

The simulation conditions when the simulation results B shown in Figure 10 were obtained were as follows: specifically, D1/D2 was set at 0.5, and the remaining conditions were the same as in the case of the simulation results A. The simulation conditions when the simulation results C shown in Figure 10 were obtained were as follows: specifically, D1/D2 was set at 0.75, and the remaining conditions were the same as in the case of the simulation results A. The simulation conditions when the simulation results D shown in Figure 10 were obtained were as follows: specifically, D1/D2 was set at 1, and the remaining conditions were the same as in the case of the simulation results A.

The simulation results A, B and C are simulation results of respective embodiments of the present invention, while the simulation results D are simulation results of a comparative example.

The simulation conditions when the simulation results E shown in Figure 11 were obtained were as follows: specifically, the dressing surface of the dressing tool 21 was constructed only from an annular region R2, with the circular region R2

eliminated; furthermore, the internal diameter of the annular region R2 was set at 80 mm, and the external diameter of the annular region R2 was set at 100 mm. The remaining conditions were the same as the conditions in the case of the simulation results A.

The simulation conditions when the simulation results F shown in Figure 11 were obtained were as follows: specifically, the dressing surface of the dressing tool 21 was constructed only from a circular region R1, with the annular region R2 eliminated; furthermore, the diameter of the circular region R1 was set at 70 mm. The remaining conditions were the same as the conditions in the case of the simulation results A.

The simulation results E and F are simulation results for examples of dressing apparatuses corresponding to respective conventional techniques. Furthermore, G in Figure 11 indicates the initial thickness distribution of the polishing pad 25 prior to dressing.

It is seen from the simulation results A through D shown in Figure 10 that the thickness of the polishing pad 25 following dressing can be flattened (compared to a case where $D1 = D2$) by setting D1 and D2 so that $D1 < D2$. In particular, in the simulation examples shown in Figure 10, the polishing pad 25 is almost completely flattened if $D1/D2$ is set at 0.25, as in the simulation results A.

In a case where the dressing surface of the dressing tool 21 is constructed only from an annular region R2, a thickness distribution that is convex in the upward direction is obtained, as in the simulation results E shown in Figure 11. On the other hand, in a case where the dressing surface of the dressing tool 21 is constructed only from a circular region R1, a thickness distribution that is concave in the downward direction is obtained, as in the simulation results F shown in Figure 11. In the simulation results A through C of embodiments of the present invention, it appears that thickness distribution characteristics are obtained in which the tendency toward a thickness distribution that is convex in the upward direction caused by the annular region R2 and the tendency toward a thickness distribution that is concave in the downward direction caused by the circular region R1 are synthesized, so that the degree of the contributions of both distributions is determined by D1/D2. In the simulation examples shown in Figure 10, it appears that the two tendencies cancel each other more or less completely when D1/D2 = 0.25, so that a more or less completely flat thickness distribution is obtained.

Since the above results are based on logical calculations by simulation, actual results will show some deviation from the simulation results. However, when the present inventors performed actual experiments, although there was some need for appropriate alteration of the numerical values of the conditions as required,

experimental results showing tendencies similar to those of the simulations were obtained. In regard to the actual conditions, for example, D1/D2, etc., may be appropriately set so that the polishing pad 25 reaches the greatest degree of flatness following dressing. Furthermore, the values of the mean distribution densities D1 and D2 themselves may be appropriately set with the particle size of the diamond particles 32, etc., being taken into account so that such a ratio is satisfied, and so that the polishing surface of the polishing pad 25 is roughened to the desired extent following dressing.

The invention of the working configuration described above using Figures 7 through 11 makes it possible to provide a dressing tool that can flatten the polishing surface of the polishing pad following dressing with good precision, and a dressing apparatus using this dressing tool.

[Third Working Configuration]

Figure 12 is a schematic structural diagram which shows in model form a polishing apparatus constituting a third working configuration of the present invention. Figure 13 is a schematic plan view which shows in model form the positional relationship between the dressing surface 53 of the dressing tool 51 and the polishing pad 44 during the dressing of the polishing pad 44.

The polishing apparatus of the present working configuration comprises a polishing tool 41, a wafer holder 43 which holds a wafer 42 beneath the polishing tool 41 positioned in a polishing station (polishing zone) indicated on the right side of the figure, a polishing agent supply part (not shown in the figures) which supplies a polishing agent (slurry) to the space between the wafer 42 and the polishing tool 41 via a supply path (not shown in the figures) formed in the polishing tool 41, a dressing apparatus 46 which is disposed in a dressing station (dressing zone) shown on the left side of the figure and which dresses the polishing surface of the polishing pad 44 of the polishing tool 41 positioned in the dressing station, a displacement meter 47 which is disposed in the dressing station, a control part 48 consisting of a computer, etc., a driving part 49 which drives the motors of various parts under the control of the control part 48, and an input part 50 such as a keyboard.

The polishing tool 41 has a polishing pad 44 and a substrate 45 which supports the surface of the polishing pad 44 on the opposite side from the polishing surface. In the present working configuration, as is shown in Figure 13, the shape of the polishing pad 44 is a ring-form shape in which the portion in the vicinity of the center of rotation is removed. However, the present invention is not limited to this; for example, this shape may also be a circular disk-form shape. The polishing tool 41 is arranged so that this tool can be rotated, moved upward and downward and caused to swing (perform a reciprocating motion) to the left and right as

indicated by the arrows A, B and C in Figure 12 by means of a mechanism (not shown in the figures) using electric motors as actuators. Furthermore, as is shown in Figure 12, the polishing tool 41 can be moved between the polishing station and the dressing station by means of a moving mechanism (not shown in the figures) using an electric motor as an actuator.

The polishing tool 41 is mechanically connected to a rotating shaft 56 via a lockable gimbal mechanism 55. Although this is not shown in the figures, this gimbal structure has basically the same construction as a conventionally used gimbal mechanism. However, this gimbal mechanism 55 also has a locking mechanism that is operated by an electromagnetic actuator, and is constructed so that this mechanism can be switched between a state in which the polishing tool 41 can be freely inclined with respect to the rotating shaft 56 under the control of the control part 48 (gimbal state), and a state in which the polishing tool 41 is fixed so that this tool cannot be inclined with respect to the rotating shaft 56 (gimbal locked state). In the gimbal locked state, the undersurface (polishing pad supporting surface) of the substrate 45 is perpendicular to the rotating shaft 56. The gimbal mechanism 55 is placed in the gimbal state in the polishing station, and is placed in the gimbal locked state in the dressing station.

The wafer 42 is held on the wafer holder 43, and the upper surface of the wafer 42 is the surface that is polished. The wafer holder 43 can be rotated as

indicated by the arrow D in Figure 12 by a mechanism (not shown in the figures) using an electric motor as an actuator.

In the present working configuration, the diameter of the polishing tool 41 is set at a value that is smaller than the diameter of the wafer 42, so that the footprint of the apparatus as a whole is small, and so that high-speed, low-load polishing is facilitated. Of course, in the present invention, the diameter of the polishing tool 41 may also be the same as or larger than the diameter of the wafer 42.

Here, the polishing of the wafer 42 by this polishing apparatus will be described. In the polishing station, the polishing tool 41 is caused to swing back and forth while rotating, and is pressed against the upper surface of the wafer 42 on the wafer holder 43 with a specified pressure (load). The wafer holder 43 is caused to rotate so that the wafer 42 is also caused to rotate, thus causing a relative motion to be performed between the wafer 42 and the polishing tool 41. In this state, a polishing agent is supplied to the space between the wafer 42 and the polishing tool 41 from the polishing agent supply part; this polishing agent diffuses between the wafer 42 and polishing tool 41, and polishes the surface of the wafer 42 that is being polished. Specifically, favorable polishing is accomplished as a result of the synergistic effect of the mechanical polishing effected by the relative motion of the polishing tool 41 and wafer 42 and the chemical action of the polishing agent.

The dressing apparatus 46 comprises a dressing tool 51. In the present working configuration, the dressing tool 51 has a circular disk-form tool body in which a ring-form part on the outer circumferential side of the upper surface is formed as a planar surface that is a step higher; this dressing tool 51 has a structure in which abrasive grains such as diamond particles are distributed on the upper surface of this ring-form part that is a step higher. The ring-form region in which these abrasive grains are distributed constitutes the dressing surface 53. Of course, the construction of the dressing tool 51 is not limited to such a construction. Furthermore, the dressing surface 53 is not limited to a ring-form surface; for example, this dressing surface 53 may also have a circular shape.

Furthermore, in the present working configuration, the dressing apparatus 46 comprises a rotating mechanism 61 which causes the dressing tool 51 to rotate as indicated by the arrow E, and an inclination adjustment mechanism 62 which can adjust and set the inclination of the dressing surface 53 in the direction indicated by the arrow F.

The inclination adjustment mechanism 62 has a bracket 64 which is fastened to a base 63, an inclining member 66 which is supported on the bracket 64 so that this member can be caused to incline by a shaft 65, and an electric motor used as an actuator (not shown in the figures). When the inclining member 66 is inclined by operating the above-mentioned electric motor, and the above-mentioned electric

motor is then stopped, the inclining member 66 is held in this position. Of course, the inclination adjustment mechanism 62 is not limited to such a structure; it goes without saying that various types of structures may be used. Although this is not shown in detail in the figures, the base side of the rotating mechanism 61 is fastened to the inclining member 66, and the rotating side of the rotating mechanism 61 is fastened to the tool main body 62 of the dressing tool 51. The rotating mechanism 61 has an electric motor (not shown in the figures) as an actuator.

The shaft 65 of the inclination adjustment mechanism 62 extends in a direction perpendicular to the plane of the page in Figure 12, and extends in a direction perpendicular to the straight line G shown in Figure 13 (i.e., a straight line that passes through the center O1 of the polishing pad 44 and the center O2 of the dressing surface 53 of the dressing tool 51 during the dressing shown in Figure 13). As a result, in the present working configuration, inclination of the dressing surface 53 about the axial line of this shaft 65 (direction indicated by the arrow F) can be adjusted and set. It is most desirable that it be possible to adjust the inclination of the dressing surface 53 in this direction F; however, the inclination adjustment mechanism 62 may also be constructed so that the inclination in some direction other than this direction is adjustable. Furthermore, in the present working configuration, the inclination adjustment mechanism 62 is constructed so that the inclination of the dressing surface 53 can be adjusted and set as described

above; conversely, however, it would also be possible to construct the inclination adjustment mechanism 62 so that the inclination of the polishing tool 41 can be adjusted and set.

As is shown in Figures 12 and 13, the dressing of the polishing surface (undersurface in the present working configuration) of the polishing pad 44 is accomplished in the same manner as polishing by pressing the polishing pad 44 of the polishing tool 41 positioned in the dressing station against the dressing surface 53 of the dressing tool 51 in a state in which a load is applied, and causing the polishing tool 41 and dressing tool 51 to rotate as indicated by the respective arrows A and E. However, the swinging motion of the polishing tool 41 in the direction indicated by the arrow C is not performed. As is shown in Figures 12 and 13, this dressing is performed in a state in which a portion of the dressing surface 53 protrudes from the polishing pad 44 on the inner circumferential side and outer circumferential side. During this dressing, the gimbal mechanism 55 is placed in the gimbal locked state; furthermore, in the inclination adjustment mechanism 62, a preset inclination of the dressing surface 53 of the dressing tool 51 is held "as is." Accordingly, during the dressing of the polishing pad 44, there is no change in the relative inclination of the dressing surface 53 with reference to the polishing pad supporting surface (undersurface) of the substrate 45 of the polishing tool 41.

In the present working configuration, the displacement meter 47 disposed in the dressing station constitutes a measuring part that obtains information corresponding to the surface shape of the polishing surface of the polishing pad 44. The displacement meter 47 obtains this information under the control of the control part 48. In the present working configuration, although this is not shown in the figures, a commercially marketed contact needle-type displacement meter is used as the displacement meter 47. This displacement meter is arranged so that the contact needle contacts the polishing surface of the polishing pad 44 and moves upward and downward in accordance with the height of this polishing surface, thus making it possible to measure the surface shape of the polishing surface of the polishing pad 44 by sliding the contact needle in the radial direction of the polishing pad 44. Furthermore, since the heights at respective positions on a circumference of the same radius on the polishing pad 44 are substantially the same, it is necessary only to measure the heights at respective positions on a single line along a given radius of the polishing pad 44. For example, it would also be possible to use an optical-type displacement meter, etc., as the displacement meter 47 instead of a contact needle-type displacement meter.

The control part 48 controls the respective parts (as ordinary control) so that the above-mentioned polishing operation is performed in the polishing station, and controls the respective parts so that the above-mentioned dressing is performed in the dressing station with a specified frequency.

Furthermore, the control part 48 also performs the inclination adjustment control shown in Figure 14. Figure 14 is a schematic flow chart which shows the operation of this inclination adjustment control. The control part 48 initiates inclination adjustment control in response to an inclination adjustment command signal from the input part 50 that is input by the operation of the operator. For example, this command signal may be sent when the dressing tool 51 is replaced with a new dressing tool. Of course, such inclination adjustment command signals may also be sent at a specified frequency within the period of use of the same dressing tool 51. The system may also be devised, for instance, so that the control part 48 itself judges a period corresponding to a preset frequency and automatically generates such inclination adjustment command signals, instead of these signals being sent from the input part 50 by the operator.

When the control part 48 initiates this inclination adjustment control, the above-mentioned dressing of the polishing pad 44 is first performed (step S1). When this dressing is completed, the control part 48 sends a control signal to the displacement meter 47 and causes the displacement meter to measure the above-mentioned surface shape of the polishing pad 44. The control part 48 inputs this surface shape data (step S2). During the measurement of this surface shape, for example, the measurement is performed in a state in which the rotation of the dressing tool 51 is stopped, the polishing surface of the polishing pad 44 is caused to

float from the dressing surface 53 of the dressing tool 51, and the polishing tool 41 is caused to rotate.

Next, the control part 48 makes a judgement as to whether or not the surface shape most recently input in step S2 is a surface shape that is within a predetermined permissible range with respect to an ideal, completely flat surface shape, and thus judges whether or not the inclination of the dressing surface 53 of the dressing tool 51 that is currently set by the inclination adjustment mechanism 62 is the desired inclination (step S3).

If it is judged in step S3 that the surface shape is not a surface shape within the above-mentioned permissible range (i.e., that the current inclination of the dressing surface 53 is not the desired inclination), the control part 48 operates the inclination adjustment mechanism 62 so that the inclination of the dressing surface 53 is adjusted to an inclination which is such that the surface shape following dressing is a surface shape that is within the permissible range or a surface shape that approaches such a surface shape within the permissible range, and sets the inclination at this inclination (step S4). The control part 48 then returns to step S1. Furthermore, with regard to the relationship between the surface shape and the inclination of the dressing surface 53, the necessary amount of inclination adjustment can be determined by using an equation or look-up table that is determined from experimental data, etc. Alternatively, the amount of inclination

adjustment can be set at a certain small fixed amount, and determined from the surface shape obtained in step S2 only in the direction of increasing or decreasing inclination.

On the other hand, if it is judged in step S3 that the surface shape is a surface that is within the permissible range, the control part 48 ends the inclination adjustment control, and performs the above-mentioned ordinary control.

In the present working configuration, as was described above, the relative inclination of the dressing surface 53 with reference to the polishing pad supporting surface (undersurface) of the substrate 45 of the polishing tool 41 is maintained at the inclination adjusted and set beforehand by the inclination adjustment mechanism 62 during the dressing of the polishing pad 44. Furthermore, as a result of the above-mentioned inclination adjustment control by the control part 48, the relative inclination of the dressing surface 53 that is finally set is unaffected by the difference in inclination between the rotating shaft of the polishing tool 41 and the rotating shaft of the dressing tool 51, and is adjusted and set at inclination which is such that a surface shape of the polishing pad 44 that is extremely close to an ideal, completely flat surface shape can be obtained.

Accordingly, in the present working configuration, factors that hinder the improvement of the flattening of the polishing pad in a polishing pad dressing

technique using angular tracking by means of a gimbal mechanism are eliminated; furthermore, the effect of the difference in inclination between the rotating shaft of the polishing tool 41 and the rotating shaft of the dressing tool 51 is completely eliminated. Accordingly, in the present working configuration, the polishing pad 44 can be dressed to a flat shape with a higher degree of precision than in conventional techniques. Furthermore, in the present working configuration, since the wafer 42 is polished in the polishing station by a polishing pad 44 that has thus been dressed to a flat state with a high degree of precision, the wafer 42 can be polished to a flat state with a high degree of precision.

Furthermore, in the present working configuration, it would also be possible to use the dressing tool 21 shown in Figure 7 instead of the dressing tool 51 . If this is done, the effects of the present working configuration described above, and the effects of using a dressing tool 21 with a special structure as described in the above-mentioned second working configuration, can both be obtained.

[Fourth Working Configuration]

Figure 15 is a schematic structural diagram which shows in model form a dressing apparatus constituting a fourth working configuration of the present invention. Figure 16 is a schematic plan view which shows in model form the

positional relationship between the dressing surface 84 of the dressing tool 72 and the polishing pad 44.

In the above-mentioned third working configuration, the dressing apparatus 46 was built into the polishing apparatus. Furthermore, in the third working configuration, the inclination adjustment performed by the inclination adjustment mechanism 62 was automated.

In contrast, the dressing apparatus of the present working configuration is constructed independently from the polishing apparatus. Furthermore, the present working configuration is constituted so that the inclination adjustment performed by the inclination adjustment mechanism is performed manually by the operator.

For example, the dressing apparatus of the present working configuration dresses the polishing surface (undersurface in Figure 15) of the polishing pad 44 used in a polishing apparatus in which the dressing apparatus 46 in the polishing apparatus shown in Figure 12 (according to the above-mentioned third working configuration) is removed.

The dressing apparatus of the present working configuration comprises a pad holder 71 which holds the polishing pad 44 by vacuum suction chucking, etc., a

dressing tool 72, an inclination adjustment mechanism 73, a raising and lowering mechanism 74, a displacement meter 75, and a display part 76.

The pad holder 71 has a circular disk-form substrate 81 which supports the surface of the polishing pad 44 on the opposite side from the polishing surface. In the present working configuration as well, the shape of the polishing pad 44 is a ring-form shape in which the portion in the vicinity of the center of rotation is removed as shown in Figure 16. However, the shape used is not limited to this shape; for example, a circular disk-form shape may also be used. The pad holder 71 can be caused to rotate as indicated by the arrow H in Figures 15 and 16 by a mechanism (not shown in the figures) that uses an electric motor as an actuator. The pad holder 71 does not perform an upward and downward motion or swinging motion. The pad holder 71 is fastened to a rotating shaft 72 without a gimbal mechanism. Accordingly, the pad holder 71 cannot tilt.

In the present working configuration, the dressing tool 72 has a tool main body 83 which has the shape of a rectangular solid; this dressing tool 72 has a structure in which abrasive grains such as diamond particles are distributed over the entire upper surface. The rectangular region over which these abrasive grains are distributed constitutes a dressing surface 84. Of course, the construction of the dressing tool 72 and the shape of the dressing surface 74 are not limited to such a construction and shape.

The inclination adjustment mechanism 73 is constructed so that the inclination of the dressing surface 84 in the direction indicated by the arrow J can be adjusted and set. The inclination adjustment mechanism 73 has a bracket 86 which is fastened to a base-side member 85, an inclining member 88 which is supported on the bracket 86 so that this member can be inclined by a shaft 87, an adjustment screw 89, a supporting member 90 which is fastened to the member 85 and which supports the adjustment screw 89 so that this screw is free to turn, a left-right moving member 91 with which the adjustment screw 89 is screw-engaged, and which can move over the member 85 to the left and right as indicated by the arrow K in Figure 15, and a lock screw (not shown in the figures) which locks the inclining member 88 to the bracket 86 at the adjusted inclination, and which releases this locking action. The upper surface of the left-right moving member 91 and the undersurface on the tip end of the inclining member 88 are formed as tapered surfaces that engage with each other. In this inclination adjustment mechanism 73, when the operator releases the above-mentioned lock screw and turns the adjustment screw 89 in one direction or the other, the left-right moving member 91 moves to the left or right in accordance with the direction and amount of this turning of the adjustment screw. Since the tapered surfaces of the left-right moving member 91 and inclining member 88 are engaged with each other, the inclination of the inclining member 88 in the direction indicated by the arrow J in Figure 15 is determined in accordance with the left-right movement of the left-right

moving member 91. The inclining member 88 and the tool main body 73 of the dressing tool 72 are fastened to each other via a connecting member 92. Accordingly, by releasing the above-mentioned lock screw and turning the adjustment screw 89 in one direction or the other, the operator can adjust the inclination of the dressing surface 84 in the direction indicated by the arrow J; furthermore, the operator can cause this inclination to be held by locking this inclination with the above-mentioned lock screw following this adjustment. Of course, the inclination adjustment mechanism 73 is not limited to such a structure; it goes without saying that various types of structures may be used.

The shaft 87 of the inclination adjustment mechanism 73 extends in a direction perpendicular to the plane of the page in Figure 15, and extends in a direction that is perpendicular to the straight line M shown in Figure 16 (i.e., a straight line that passes through the center O1 of the polishing pad 44 and the center O3 of the dressing surface 84 of the dressing tool 72 during the dressing shown in Figure 16). As a result, in the present working configuration, the inclination of the dressing surface 84 about the axial line of this shaft 87 (the direction indicated by the arrow J) can be adjusted and set. It is most desirable that it be possible to adjust the inclination of the dressing surface 84 in this direction J; however, the inclination adjustment mechanism 73 may also be constructed so that the inclination in some direction other than this direction is adjustable. Furthermore, in the present working configuration, the inclination

adjustment mechanism 73 is constructed so that the inclination of the dressing surface 84 can be adjusted and set as described above; conversely, however, it would also be possible to construct the inclination adjustment mechanism 73 so that the inclination of the pad holder 71 can be adjusted and set.

The raising and lowering mechanism 74 is constructed by a cylinder. Specifically, the raising and lowering mechanism 74 has a cylinder tube 94 which is fastened to a base 93, a piston 95 which is inserted into the cylinder tube 94 so that this piston 95 is free to slide in the axial direction (vertical direction), and a piston rod 96 which is connected to this piston 95, and which passes through the cylinder tube 94 and extends upward. The upper end of the rod 96 is fastened to the member 85. By appropriately setting the supply and discharge of air and the pressure in the compartments on both sides demarcated by the piston 95 inside the cylinder tube 94, it is possible to move the piston rod 96 upward and downward in the direction indicated by the arrow L, and to determine the pressing force exerted on the polishing pad 44 by the dressing surface 84 of the dressing tool 72.

Like the displacement meter 47 shown in Figure 12, the displacement meter 75 constitutes a measuring part that obtains information corresponding to the surface shape of the polishing surface of the polishing pad 44; the same displacement meter used as the displacement meter 47 can also be used here. The display part 76 displays the surface shape measured by the displacement meter 75.

In the present working configuration, as is shown in Figures 15 and 16, the dressing of the polishing surface (the undersurface in the present working configuration) of the polishing pad 44 is accomplished by raising the dressing tool 72 by means of the raising and lowering mechanism 74 so that the polishing pad 44 is pressed against the dressing surface 84 of the dressing tool 72 in a state in which a load is applied, and by causing the pad holder 71 to rotate as indicated by the arrow H. As is shown in Figures 15 and 16, this dressing is performed in a state in which a portion of the dressing surface 84 protrudes from the polishing pad 44 on the outer circumferential side and inner circumferential side. During this dressing, the inclination of the pad holder 71 does not change; furthermore, the inclination of the dressing surface 84 of the dressing tool 72 set beforehand by the inclination adjustment mechanism 73 is held "as is." Accordingly, during the dressing of the polishing pad 44, there is no change in the relative inclination of the dressing surface 84 with reference to the polishing pad supporting surface (undersurface) of the substrate 81 of the pad holder 71.

In the present working configuration, the operator performs a function that more or less corresponds to the inclination adjustment control function (shown in Figure 14) of the above-mentioned control part 48 shown in Figure 12. Specifically, the operator first causes the above-mentioned dressing operation to be performed. When this dressing is completed, the operator measures the surface shape of the

polishing pad 44 using the displacement meter 75, and displays the measured surface shape on the display part 76. Then, the operator views the surface shape displayed on the display part 76, and judges whether or not the inclination of the dressing surface 84 of the dressing tool 72 currently set by the inclination adjustment mechanism 73 is the desired inclination by judging whether or not this surface shape is a surface shape that is within the predetermined permissible range for an ideal, completely flat surface shape. In cases where the surface shape is not a surface shape that is within the permissible range, the operator adjusts the inclination of the dressing surface 84 by means of the inclination adjustment mechanism 73 on the basis of the surface shape displayed by the display part 76 so that the surface shape following dressing is adjusted to a surface shape within the permissible range or a surface shape that approaches such a surface shape, and sets the inclination at this inclination. Then, the operator repeats the above-mentioned operation until the surface shape that is measured and displayed is adjusted to a surface shape that is within the permissible range. Once a surface shape that is within the permissible range is obtained, the adjustment of the inclination of the dressing surface 84 is ended; furthermore, the dressing of the polishing pad 44 is completed.

In the present working configuration, since work by an operator is required, the operation is slightly more complicated than in the case of the above-mentioned third working configuration; however, as in the case of the above-mentioned first

working configuration, the polishing pad 44 can be dressed to a flat state with a higher degree of precision than in conventional techniques.

Incidentally, in the above-mentioned third working configuration, it would also be possible to install the inclination adjustment mechanism 73 and connecting member 92 shown in Figure 15 instead of the inclination adjustment mechanism 62 and rotating mechanism 61 shown in Figure 12. Conversely, in the above-mentioned fourth working configuration, it would also be possible to install the inclination adjustment mechanism 62 and rotating mechanism 61 shown in Figure 12 instead of the inclination adjustment mechanism 73 and connecting member 92 shown in Figure 15. In this case, if a control part and input part that perform a control procedure corresponding to the above-mentioned operation of the operator are installed, automation can also be achieved in a dressing apparatus that is independent of the polishing apparatus. In cases where automation is achieved in such an independent dressing apparatus, it is not absolutely necessary to install a displacement meter 75 in the dressing apparatus. In this case, the surface shape of the polishing surface of the polishing pad 44 may be measured by a separate displacement meter that is independent from the dressing apparatus in a state in which the polishing pad 44 is temporarily removed from the pad holder 71, and the data may be input into the control part from the input part.

Furthermore, in the case of a polishing apparatus in which the dressing apparatus 46 is removed from the polishing apparatus according to the above-mentioned third working configuration shown in Figure 12, the use of a polishing pad 44 that is dressed by the dressing apparatus of the above-mentioned fourth working configuration results in a polishing apparatus according to another working configuration of the present invention.

[Fifth Working Configuration]

Figure 17 is a flow chart which shows a semiconductor device manufacturing process that constitutes a working configuration of the present invention. The semiconductor device manufacturing process is started, and an appropriate treatment process is first selected in step S200 from the subsequently shown steps S201 through S204. The processing then proceeds to one of these steps S201 through S204 in accordance with this selection.

Step S201 is an oxidation process in which the surface of the silicon wafer is oxidized. Step S202 is a CVD process in which an insulating film is formed on the surface of the silicon wafer by CVD, etc. Step S203 is an electrode formation process in which electrode films are formed on the surface of the silicon wafer by a process such as vapor deposition. Step S204 is an ion injection process in which ions are injected into the silicon wafer.

Following the CVD process or electrode formation process, the processing proceeds to step S209, and a judgement is made as to whether or not a CMP process is to be performed. In cases where such a process is not to be performed, the processing proceeds to step S206; however, in cases where such a process is to be performed, the processing proceeds to step S205. Step S205 is a CMP process; in this process, flattening of the inter-layer insulating film, or the formation of a damascene by the polishing of a metal film on the surface of the semiconductor device, etc., is performed using the polishing apparatus of the present invention.

Following the CMP process or oxidation process, the processing proceeds to step S206. Step S206 is a photolithographic process. In this photolithographic process, the silicon wafer is coated with a resist, a circuit pattern is burned onto the silicon wafer by exposure using an exposure apparatus, and the exposed silicon wafer is developed. Furthermore, the subsequent step S207 is an etching process in which the portions other than the developed resist image are removed by etching, after which the resist is stripped away, and the resist that has become unnecessary following the completion of etching is removed.

Next, in step S208, a judgement is made as to whether or not all of the necessary processes have been completed. In cases where these processes have not been completed, the processing returns to step S200, and the preceding steps are

repeated so that a circuit pattern is formed on the silicon wafer. If it is judged in step S208 that all of the processes have been completed, the processing is ended.

In the semiconductor device manufacturing method of the present invention, since the polishing apparatus of the present invention is used in the CMP process, wafers can be polished to a flat state with a high degree of precision. Accordingly, the following effect is obtained: namely, the yield of the CMP process is increased, so that semiconductor devices can be manufactured at a lower cost than in conventional semiconductor device manufacturing methods.

Furthermore, the polishing apparatus of the present invention may also be used in the CMP processes of semiconductor device manufacturing processes other than the above-mentioned semiconductor device manufacturing process.

As a result, the semiconductor device manufacturing method of the present invention makes it possible to manufacture semiconductor devices at a lower cost than conventional semiconductor device manufacturing methods, so that the manufacturing cost of semiconductor devices can be reduced.

Industrial Applicability

The dressing tool and dressing apparatus of the present invention can be used in the dressing of the polishing pad in a polishing apparatus, etc. Furthermore, the working apparatus of the present invention can be used as (for example) a polishing apparatus in the polishing of wafers in a semiconductor device manufacturing process. Moreover, the semiconductor device manufacturing method of the present invention can be used to manufacture semiconductor devices that have fine patterns.